Appendix E
Draft Technical Memorandum, Failure Modes and Effects Analysis, Bunker Hill Water Collection and Treatment System, Bunker Hill Mining and Metallurgical Complex Superfund Site (January 10, 2014)

Failure Modes and Effects Analysis – Bunker Hill Water Collection and Treatment System

Bunker Hill Mining and Metallurgical Complex Superfund Site

PREPARED FOR: U.S. EPA Region 10

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This technical memorandum (TM) presents a Failure Modes and Effects Analysis (FMEA) developed for the mining-influenced water (MIW) collection and treatment system at the Bunker Hill Mining and Metallurgical Complex Superfund Site, in the Coeur d'Alene River Basin, Idaho. This FMEA was developed in conjunction with the schematic design phase of the Phase 1 Central Treatment Plant (CTP) Upgrades and Central Impoundment Area Groundwater Collection System (GWCS) remedial design project. This FMEA updates an earlier one performed for the Bunker Hill water collection and treatment system in January 2003 (CH2M HILL, 2003).

FMEA Assumptions and Results

This FMEA considered all aspects of the Bunker Hill MIW collection and treatment system, including existing components and future components associated with the Phase 1 CTP Upgrades and GWCS design. It was developed from the perspective that all elements of the design are constructed. The FMEA assumes that a primary goal of the GWCS is to prevent any bypass of groundwater past the extraction well array/cutoff wall or any ponding of water above the ground surface. In other words, for this FMEA, any migration of groundwater past the GWCS, which is not captured by an extraction well and, therefore, would eventually reach the South Fork Coeur d'Alene River (SFCDR, or "river") was considered a failure of this primary goal. CH2m HILL recognizes that this is a conservative assumption, especially considering the other non-point sources of MIW that enter the SFCDR both upstream and downstream of the GWCS. CH2M HILL recommends that EPA consider the results of this FMEA with this assumption in mind.

The FMEA results are presented in Table 1. This table is divided into system components. For each component, it lists failure modes, effects of failure, possible solutions, and a priority category or rating. Table 2 describes the categories used in the FMEA. For categories A, B, and C, the priority ranking consists of two main elements: (1) severity of effects and, in some cases, duration of effects; and (2) probability of occurrence. In assigning categories to failure modes, these elements were sometimes "averaged". For example, a failure mode with severe (A-level) consequences but a low (C-level) likelihood of occurring might be given a "B" ranking.

Four of the identified failure modes were assigned the "A" priority category:

- Loss of ability to divert acid mine drainage (AMD) to the mine pool for in-mine storage, as needed. The ability to utilize in-mine storage in a timely fashion is critical for mitigating effects of system component failures.
- Avista power outage at the GWCS. This would cause a temporary shutdown of extraction well pumps until generator power could be brought online. The GWCS design includes provision of portable power generators (four are anticipated; one for each utility service location) to operate the entire GWCS, but it is doubtful that these could be set up, started up, and operated until Avista power is restored without some bypass of contaminated groundwater to the river (which is predicted by modeling to occur within a few hours). As described above, this is assumed to correspond to the assumed definition of GWCS failure.

- Accumulation of mine water precipitates, sediment, and/or water in the Lined Pond to the extent that the available storage capacity is appreciably reduced. The Lined Pond is currently the only place where extracted groundwater can be diverted for storage, so maximizing the available storage capacity of the Lined Pond is critical for maintaining groundwater collection during short-term CTP shutdowns (planned or unplanned).
- Fire damage in the CTP control building resulting from the lack of an automatic fire suppression system.

In addition to the items above, it is important to note that there will be no way to maintain GWCS operation during an extended CTP shutdown in the future, unless other provisions are made (possible options are cited in Table 1, GWCS section). Nearly all of the AMD can be diverted to in-mine storage for an extended period, but extracted groundwater can only be diverted to the Lined Pond, and for a limited duration. For example, assuming an available storage capacity in the Lined Pond of 6 million gallons (MG)[1] and a groundwater flow of 2,000 gallons per minute (gpm), the storage capacity would be exhausted in approximately 2 days. Consequently, while extended CTP shutdown events are expected to be rare, they will undoubtedly occur at some time in the future. For instance, in 2003 the CTP was off-line for about 3 weeks during a planned maintenance shutdown for thickener repairs.

TABLE 2
FMEA Category Definitions

Category	Description	Definition
A	High Priority	High risk of severe consequences. Failure would have serious effects, could have an extended duration, and is considered to have a relatively high probability of occurrence. Most of these items would result in release of contaminated water if failure occurred.
B	Medium Priority	Moderate risk of severe consequences. Severity of effects, duration, and/or probability of occurrence of failure are considered to be moderate and lower than for Category A items. Many of these items would result in release of MIW if the failure mode occurred.
C	Lower Priority	Lower risk of severe consequences. Duration and probability of failure considered to be relatively low, and lower than for Category B items.
O	O&M Issue	Failure mode can be addressed and/or prevented via good operations and maintenance (O&M) practices.

References

CH2M HILL. 2003. Failure Modes and Effects Analysis – Bunker Hill Water Collection and Treatment System. Prepared for U.S. EPA Region 10, January 13, 2003.

Abbreviations

AMD	acid mine drainage
CTP	Central Treatment Plant
FMEA	Failure Modes and Effects Analysis
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
GWCS	Groundwater Collection System

[1] The total capacity of the Lined Pond is 7-7.5 MG, but it is rarely completely empty, because of accumulated sediment and accumulation of relatively small flows of PTM/004-Sweeny water and mine yard stormwater.

MG	million gallons
MIW	mining-influenced water
O&M	operations and maintenance
SFCDR	South Fork Coeur d'Alene River
TM	technical memorandum

TABLE 1

Failure Mode and Effects Analysis - Bunker Hill Water Collection and Treatment System

No.	Failure Mode	Effects	Solution	Cat.[a]
In-Mine AMD Storage				
1	Loss of ability to divert acid mine drainage (AMD) to the mine pool for in-mine storage, as needed (e.g., due to failure of diversion facilities, or failure to effect diversion in a timely fashion).	Unabated discharge of AMD from mine when downstream systems are inoperative will result in release of AMD to ground and eventually to Bunker Creek (creek). Also, mine water flows >5,000 gpm could exceed CTP hydraulic capacity.	The ability to utilize in-mine storage is critical for mitigating effects of system component failures. Provide and maintain means to rapidly divert partial or complete mine water flow to the lower workings. Maintain supply of sandbags near diversion location. Ensure mine operations staff are familiar with diversion construction procedures.	A, O
Kellogg Tunnel (KT) Portal Area				
2	High AMD flows bypass ditch. High AMD flows travel down tunnel floor and exit the portal outside the ditch.	AMD release to ground in mine yard and downgradient areas, eventually to creek.	Construct cross-drop ditch at portal to capture and direct AMD flow into ditch. Divert AMD to in-mine storage if needed.	C
3	AMD flow rate exceeds concrete ditch capacity outside portal (7,000 gpm).	AMD release to ground in mine yard and downgradient areas, eventually to creek.	Divert AMD to in-mine storage until flows recede and/or turn off mine pool pumps.	O
4	Trash rack clogs or ditch fills with sediment.	AMD release to ground in mine yard and downgradient areas, eventually to creek.	Maintain trash racks and ditch in clean condition through regular inspection and cleaning.	O
Mine Water Pipelines				
5	Pipeline plugging or breaching.	AMD release to ground, eventually to creek.	If plug or breach is in the Lined Pond branch (between tee and Lined Pond), divert flow through the Direct Feed branch to CTP while effecting repairs. If problem is in the Direct Feed branch, divert flow to the Lined Pond and/or in-mine storage while effecting repairs. If problem is in the Mainline (between portal and tee), divert flow to in-mine storage and/or to old pipeline (capacity <1,000 gpm) while effecting repairs. More importantly, perform routine maintenance (e.g., pigging) to avoid pipeline plugging (this has proven to be effective over a number of years).	C, O
6	Flow rate exceeds pipe capacity (7,000 gpm).	AMD release to ground, eventually to creek.	Divert AMD to in-mine storage and/or old pipeline (capacity < 1,000 gpm) until flows recede and/or turn off mine pool pumps.	O
7	Pig becomes stuck during pipeline cleanout.	Pipe plugging and AMD release to ground, eventually to creek.	If pig is stuck in the Lined Pond branch (between tee and lined pond), divert flow through the Direct Feed branch to CTP until pig is removed. If pig is stuck in the Direct Feed branch, divert flow to the Lined Pond and/or in-mine storage while effecting repairs. If pig is stuck in the Mainline (between portal and tee), divert flow to in-mine storage and/or to old pipeline (capacity <1,000 gpm) while effecting repairs.	O
PTM-004/Sweeny Pipeline				
8	Collection manhole overflows.	Contaminated water released to road and ditch, eventually to creek.	Periodic inspection and cleaning of manhole.	O
9	Pipeline plugging.	Contaminated water released to road and ditch, eventually to creek.	Locate and clear obstruction.	B
CIA Groundwater Collection System				
Electrical, Instrumentation, Control, and Alarm Systems				
10	Avista power outage at GWCS.	Temporary shutdown of extraction pumps until generator power is brought online. Bypass of contaminated groundwater to river and/or ponding will occur quickly following shutdown (within a few hours).	Design includes provision of portable power generators to operate entire GWCS. Setup, startup, and operate portable diesel generators until Avista power is restored.	A, O
11	Failure of PLC power supply.	Automatic control lost for affected well until power supply replaced.	Well pump must be operated manually until failed power supply is replaced.	C, O
12	PLC module failure, including CPU.	Automatic control temporarily lost for items connected to failed module until replaced.	Recommend maintaining shelf spares of each module type to allow fast replacement. Replace failed module and procure new spare.	C, O
13	HMI server hard drive failure.	For a single hard drive failure, there is no disruptive effect. A loss of multiple hard drives in a single server will cause the server to fail and lose all data.	Servers are equipped with 3 hard drives each. For these servers, 2 working drives are required for operation. Replace failed hard drive as soon as practical.	O
14	Other HMI Server failures.	No disruptive effect.	Redundant servers / HMI's are networked to redundant workstations. Repair or replace failed server at earliest opportunity.	O
15	Vandalism resulting from limited security provisions at site.	Vandalism damage or non-malicious trespassing. Depending on extent of vandalism, well could be out of service for an extended period.	Protective enclosure will be provided for each wellhead to reduce the potential for vandalism.	C
Groundwater Collection System Equipment				
16	Failure of "noncritical" extraction well pump.	Should not cause disruptive effects because have 2 "extra" wells with installed pumps that can be brought online, and surplus pumping capacity at each pump (300 gpm capacity versus 200 gpm projected flow) that can be used, to mitigate effects of failed pump.	Operate spare extraction well(s) and/or primary wells at higher flow rates to maintain groundwater capture, while repairing or replacing failed pump.	C, O
17	Failure of "critical" extraction well pump on western end of groundwater collection system. [**Note**: there is a possibility that failure of this well could not be entirely compensated for by use of "extra" wells and pumping higher flow rates. This is currently being assessed by groundwater modeling. If true, installation of a backup critical well might be indicated.]	TBD	TBD	TBD

TABLE 1

Failure Mode and Effects Analysis - Bunker Hill Water Collection and Treatment System

No.	Failure Mode	Effects	Solution	Cat.[a]
18	Pipeline plugging .	Pipeline blockage would cause partial or total shutdown of groundwater conveyance, and could result in bypass of contaminated groundwater to river and/or ponding within a few hours.	Identify location and clear blockage as soon as possible. More importantly, perform routine maintenance (e.g., pigging) to avoid this failure mode. Recommend rigorous testing after system startup to evaluate appropriate (conservative) frequency of pigging. With proper routine maintenance, this failure mode should be preventable, as it has been for the mine water pipelines.	B, O
19	Pig becomes stuck during pipeline cleanout.	Would cause partial or total shutdown of groundwater conveyance, and could result in bypass of contaminated groundwater to river and/or ponding within a few hours.	Identify location and clear blockage as soon as possible. Recommend use of tracking pigs, and recommend that a pigging test be conducted at startup.	B
20	Short-term CTP shutdown or partial CTP shutdown.	No disruptive effects if CTP is back online before Lined Pond fills with diverted groundwater.	Divert extracted groundwater to Lined Pond for storage (and divert AMD to in-mine storage) until CTP is back online. Assuming 6 MG available storage in Lined Pond and 2,000 gpm groundwater flow, the Lined Pond would fill within approximately 2 days. If Lined Pond is filled with diverted groundwater before CTP is completely back online, it might be possible to achieve partial treatment in the CTP, depending on which component is down.	B
21	Unplanned long-term CTP shutdown (i.e., longer than ability to store extracted groundwater in Lined Pond)	Groundwater would bypass collection system and be released to river and ground surface (ponding).	There are no existing options for managing groundwater during an extended CTP shutdown after the Lined Pond is filled. Possible emergency options include: pumping groundwater to the existing Sludge Pond, pumping to the mine pool, pumping to a newly constructed sludge pond or water storage pond, or treatment using temporary treatment facilities. Any of these options would require infrastructure. Recommend consider adding capability to facilitate implementation of one of these options. Alternatively, could consider effects of allowing limited bypass of groundwater.	B
22	Planned long-term CTP shutdown for maintenance/repairs (i.e., longer than ability to store extracted groundwater in Lined Pond)	No effects with proper planning.	There are no existing options for managing groundwater during an extended CTP shutdown after the Lined Pond is filled. Make prior provisions for storage or temporary treatment of groundwater during CTP downtime.	O
23	Higher than expected mine water flows.	No disruptive effects on groundwater collection and treatment.	Divert AMD flow greater than 5,000 gpm to in-mine storage, and maintain required flow of groundwater to CTP (i.e., prioritize treatment of groundwater because it has only a short-term storage option).	C, O
24	Extraction well fouling.	Well fouling would cause partial or total shutdown of the affected extraction well. Well fouling may not cause disruptive effects because have 2 "extra" wells with installed pumps, and some surplus pumping capacity at each pump. Fouling of multiple wells could result in bypass of contaminated groundwater to river or ponding.	Identify fouling early and perform maintenance to clean well screen. Recommend rigorous monitoring (e.g., pressure, pump performance) and inspection after system startup to evaluate proper frequency of well cleaning. Develop routine maintenance program to avoid this failure mode, to the extent practical.	B, O
Lined Pond				
25	Accumulation of mine water precipitates, sediment, and/or water in the Lined Pond to the extent that the available storage capacity is apppreciably reduced.	Lack of sufficient storage, when needed, could result in release of MIW to the environment and eventually to the creek or river.	Clean out Lined Pond as needed to maintain good storage capacity. Normally operate CTP in direct feed mode to reduce accumulation of precipitates and sediment in Lined Pond to maximize storage capacity. Maintain maximum storage capacity by working off water inventory via treatment at the CTP as soon as practical.	A, O
26	Liner failure. May be difficult to detect unless leakage is substantial because Lined Pond has no level indication.	MIW release to ground, eventually to creek.	Prevent inflow and drain Lined Pond to expose leak, and repair. This might require pumping contents to the CTP for treatment (during low flow periods) or pumping to CTP along with diversion of AMD to in-mine storage (during higher flow periods), and will depend on the level in the pond, AMD flow rate, and CTP capacity. The liner should be inspected after the Lined Pond clean-out is completed. Recommend adding level indicator and signal with alarm at CTP to allow detection. Consider periodic liner inspection.	C, O
27	Pond overflow. Lined Pond currently has no level indicator or alarm at CTP. Operators currently monitor level manually.	MIW release to ground, eventually to creek. Released MIW would run downhill, across bike path, and eventually to Bunker Creek. Current configuration of overflow could lead to flooding of pump station.	Divert inflow from Lined Pond. Pump MIW from Lined Pond to the CTP for treatment. During higher mine water flow periods, may require diversion of AMD to in-mine storage. Hard pipe overflow line to creek to prevent exposure of people using bike path and flooding of pump station. Recommend adding level indicator and signal with alarm at CTP to allow detection.	C, O
28	Failure of old (unused) Sludge Pond decant inlet valve in NE corner of Lined Pond.	MIW release to ground, eventually to creek.	This old carbon steel valve is rusted and could fail if submerged for an extpended period of time. Recommend replacing valve with stainless steel blind flange. [**Note**: this might have already been done. Need to confirm with site operator.]	C
29	Broken Lined Pond pump station flashing alarm light intended to notify CTP operators of pump station failure.	Pump station failure may go unnoticed. Lined Pond could eventually overflow and release MIW to ground, eventually to creek. This failure mode is considered unlikey because operators visit Lined Pond for O&M daily.	Repair flashing alarm light. Recommend adding pond level indicator and signal with alarm at CTP. [**Note**: this might have already been done. Need to confirm with site operator.]	C
30	Pond outlet plugging.	Could restrict flow to wet well, pump station, and CTP. Under certain conditions, could lead to overflow of Lined Pond.	Divert inflow from Lined Pond and clear blockage.	O

TABLE 1

Failure Mode and Effects Analysis - Bunker Hill Water Collection and Treatment System

No.	Failure Mode	Effects	Solution	Cat.[a]
31	Trash rack fouling, especially because debris falls back into well when trash rack is removed for cleaning.	Could restrict flow to pump station and CTP. Under certain conditions, could lead to overflow of Lined Pond and Wet Well. This failure mode is considered unlikely because screen is cleaned daily.	Maintain trash rack in clean condition through regular inspection and cleaning. Trash rack is pulled out and cleaned manually as a routine maintenance activity, but screen design allows debris to fall off during removal. Modify screen design to retain debris as it is raised (e.g., attach a basket to bottom of screen to catch debris). [**Note**: this might have already been done; confirm with site operator.]	C, O
32	Pump station pipe breakage.	Flooding of pump station. MIW release to ground. MIW would run downhill, across bike path, and eventually to creek.	Install pump station drain lines that tie into Wet Well overflow line to creek, to prevent exposure of people using bike path. [**Note**: this might have already been done; need to confirm with site operator.]	C
33	Pump failure.	Effects considered unlikely because redundancy exists - pump station contains 3 pumps and normally only 1 or 2 are used at a time.	Use other pump(s) while failed one is repaired.	O
34	Piping plugging or failure between Lined Pond and CTP.	Plugging would restrict or prevent flow to CTP and defeat purpose of Lined Pond. Failure would release MIW to ground, and eventually to creek.	Divert inflow from Lined Pond until fixed. Inspect and repair pipes as needed. Condition of pipeline is unknown. There is no ability to pig the Lined Pond-CTP pipeline. Consider adding a pig launching station to this pipeline.	B
35	Avista power outage at Lined Pond.	No disruptive effects from short-term outage. MIW release to ground, and eventually to creek, if overflow occurs.	There is no backup power for Lined Pond pump station. Divert inflow from Lined Pond until power retored.	O
Central Treatment Plant (CTP)				
Electrical, Instrumentation, Control, and Alarm Systems				
36	Avista power outage at CTP.	Brief shutdown of CTP. Automatic startup of diesel generators.	Maintain generators, and test automatic transfer switch and generators periodically.	O
37	Failure of PLC power supply (PLCs in Control Building, Filter Building, and Lime Silo).	No disruptive effect.	Redundant power supplies provided for all CTP PLCs. In the event of a power supply failure, the backup power supply runs PLC, and a SCADA alarm notifies operator of failure. Replace failed power supply as soon as practical.	O
38	PLC module failure, including CPU.	Automatic control temporarily lost for items connected to failed module, until replaced.	Recommend maintaining shelf spare of each module type to allow fast replacement. Replace failed module and procure new spare as soon as practical.	C, O
39	HMI server hard drive failure.	For a single hard drive failure, there is no disruptive effect. Loss of multiple hard drives in a single server will cause the server to fail and lose all data.	Servers are equipped with 3 hard drives each. For these servers, 2 working drives are required for operation. In the event of failure, replace the failed hard drive as soon as practical.	O
40	Other HMI Server failures.	No disruptive effect.	Redundant servers / HMI's are networked to redundant workstations. Repair or replace the failed server at earliest opportunity.	O
41	Loss of control communication to pumps, motors, or instruments (e.g., wire breakage).	Loss of automated functions associated with affected item.	Local control and monitoring is provided. Operate manually until repairs effected.	C
42	Fire damage in CTP control building resulting from lack of an automatic fire suppression system.	If a fire in the CTP control building is not immediately controlled, the CTP could be out of service for an extended period while repairs are made.	Install automatic fire alarm and suppression system inside the CTP control building.	A
43	Vandalism of site components resulting from limited security provisions at site.	Vandalism damage or non-malicious trespassing. Depending on extent of vandalism, CTP could be out of service for an extended period.	Perform security audit and upgrades. Audit should include all components of water collection and treatment system.	C
Reactor B				
44	Mixer motor, gearbox, shaft, or impeller failure.	Solids build-up in affected Reactor B tank, poor mixing and pH/lime addition control, incomplete oxidation of reduced metals, and deterioration of mine water treatment in general.	Bypass affected reactor, and repair or replace broken equipment. This could require diversion of influent water to Lined Pond or in-mine storage.	C
45	Aeration blower failure.	Incomplete oxidation of reduced metals.	The 2 aeration blowers are sized to accommodate aeration of both Reactor B tanks at peak flow, so will have considerably redundancy under base flow conditions. If failure occurs during high flow, might necessitate temporary diversion of AMD to in-mine storage. Recommend maintaining an inventory of spare parts.	C
46	pH probe or signal failure.	Accurate pH measurement and feedback is essential to optimum CTP operation and treatment performance. Failure of this system would result in deterioration of effluent quality and/or inefficient lime use.	Repair or replace failed equipment immediately. Calibrate and clean probes every shift or as needed. Maintain spares at CTP.	B, O
Polymer System				
47	Dry polymer make-up system failure.	If not addressed in a timely fashion, polymer delivery could be interrupted, causing reduction in solids settling efficiency in Thickener.	Repair or replace failed components. If necessary, make up polymer manually until repairs completed. Maintain inventory of key spare parts.	C
48	Polymer make-up tank mixer failure.	If not addressed in a timely fashion, polymer delivery could be interrupted, causing reduction in solids settling efficiency in Thickener.	Maintain spare mixer. Install spare and repair or replace failed unit.	C
49	Polymer transfer pump or feed pump failure.	If not addressed in a timely fashion, polymer delivery could be interrupted, causing reduction in solids settling efficiency in thickener. If addressed promptly, no effects of failure of 1 pump.	There are installed duty standby pumps for both polymer transfer and feed. Switch to standby and repair or replace failed pump.	C
50	Polymer line plugging or failure.	Temporary interruption of polymer delivery.	Flush plugged lines with water to clear using flushing ports provided. Replace failed lines. If plugging recurs, recommend making periodic flushing a routine maintenance item.	C
Thickener				

TABLE 1

Failure Mode and Effects Analysis - Bunker Hill Water Collection and Treatment System

No.	Failure Mode	Effects	Solution	Cat.[a]
51	Rake drive motor or gear failure.	Conveyance of settled sludge to center would cease. This would negatively effect sludge removal and recycling, and would require shutdown of CTP to prevent over-torque of rake mechanism.	Repair or replace failed parts. Recommend refurbishing the old (unused) drive head at the site, if possible. Consider maintaining a suppply of key parts, if practical. [**Note**: the old drive unit might not be compatible with a new rake lift, if installed. Will discuss with FLSmidth.]	B
52	Underflow line plugging or failure.	There are 3 underflow lines between the Thickener and Pump Room, so plugging of one would not necessarily disrupt operations. Plugging requires temporary system shutdown while lines are flushed. Failure would release metals sludge and water to ground, and would require shutdown until repairs are effected (could be an expended duration).	Inspect and repair or clean lines, as needed. Lines have plugged in the past and are difficult to clean out. Condition of lines is unknown.	B
53	Rake overtorque causing rake shutdown.	Conveyance of settled sludge to center would cease, requiring shutdown of CTP.	Shutdown CTP and influent flow. Attempt to relieve overtorque by air-lancing or water jetting under rake and/or drain thickener and manually remove sludge. Recommend installing a rake lift. Without a lift, recommend doing testing to evaluate maximum safe underflow percent solids.	B
Sludge System				
54	Sludge recycling/wasting pump failure.	Under current operating conditions, there is adequate redundancy to avoid serious effects from failure of one pump.	Use alternate pump for failed one. Repair or replace failed pump as soon as practical.	C, O
55	Loss of city water supply.	Loss of pump seal (cooling) water could result in pump damage, but process water (effluent) can be used as backup. Should be no disruptive effects if problem is identified and change in water supply is made promptly.	Switch over to use of effluent for cooling water supply (provided as a backup system).	C, O
56	Sludge recycling or wasting line plugging.	Plugging would prevent sludge recycling or wasting and eventually cause CTP shutdown.	Flush out affected line with process water, as needed, via flushing ports provided. Flushing of sludge lines after use should be a routine maintenance item.	C, O
Reactor A				
57	Mixer motor, gearbox, shaft, or impeller failure.	Loss of mixing and good sludge/lime contact, reduced pH control, and reduced treatment system performance. Solids build-up in bottom of tank.	Operated system temporarily without mixer if needed. Repair or replace the failed parts as soon as practical.	C
Lime System				
58	Loss of water supply for lime slurry make-up.	No disruptive effects because have alternate supply (City water or CTP effluent).	Switch to alternate water supply until failure is resolved.	O
59	Failure of lime make-up system conponents: silo, feeder, slaker, slurry feed pump, slurry feed loop, lime slurry feed control valve).	No disruptive effects except under max flow/strength conditions because these systems have redundancy at normal flow/strength conditions.	Use redundant lime makeup and feed system component in lieu of failed one. Repair or replace failed component as soon as practical.	C
60	Failure of lime slurry tank mixer.	Interruption of lime slurry feed and shutdown of CTP, until fixed.	Recommend having spare mixer at the CTP. If have a spare, replace failed unit with spare, and repari or replaced failed unit. [**Note**: check with site operator to confirm whether a spare they have a spare mixer on-hand.]	B
61	Lime demand exceeds lime delivery capacity.	Temporary deterioration of CTP performance and effluent quality. This is considered unlikely because the Lime System was conservatively designed, and its capacity is adequate to meet the expected maximum demand from AMD plus extracted groundwater.	Divert AMD water to in-mine storage and/or shut down mine pool pumps.	C
Filter System				
62	Filter feed sump mixer failure.	Solids settling and accumulation in tank.	Repair or replace failed mixer.	B
63	Dirty backwash tank mixer failure.	Solids settling and accumulation in tank.	Repair or replace failed mixer.	B
64	Filter feed pump failure.	No disruptive effects because have installed spare pump.	Switch to spare pump and repair or replace failed unit.	O
65	Backwash supply pump failure	No disruptive effects because have installed spare pump.	Switch to spare pump and repair or replace failed unit.	O
66	Dirty backwash return pump failure.	No disruptive effects because have installed spare pump.	Switch to spare pump and repair or replace failed unit.	O
67	Filter feed valve failure.	Loss of ability to automatically control influent flow, to allow backwashing.	Close valve manually and take filter out of service until valve or actuator is repaired or replaced. Alternatively, operate valve manually to continue using filter.	C
68	Backwash supply valve failure.	Loss of ability to automatically control backwash supply flow for filter backwashing.	Close valve manually and take filter out of service until valve or actuator repaired or replaced. Alternatively, operate valve manually to continue using filter.	C
69	Dirty backwash valve failure.	Loss of ability to automatically control dirty backwash water flow during filter backwashing.	Close valve manually and take filter out of service until valve or actuator repaired or replaced. Alternatively, operate valve manually to continue using filter.	C
70	Air scour valve failure.	Loss of automatic control of air scour during filter backwashing.	Take filter out of service or operate valve manually. Repair or replace failed valve/actuator.	C
71	Effluent valve failure.	Loss of ability to automatically control water level/flow through filter during filter operation.	Take filter out of service. Repair or replace failed valve/actuator.	C
72	Air scour blower failure.	No disruptive effects because have installed spare blower.	Use spare blower and repair or replace failed unit.	O
Effluent System				
73	Effluent pump failure	No disruptive effects because have installed spare pump.	Use spare pump and repair or replace failed unit.	O
74	Process water pump failure	No disruptive effects because have installed spare pump.	Use spare pump and repair or replace failed unit.	O

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Failure Mode and Effects Analysis - Bunker Hill Water Collection and Treatment System

No.	Failure Mode	Effects	Solution	Cat.[a]
75	pH adjustment pump failure	No disruptive effects because have installed spare pump.	Use spare pump and repair or replace failed unit.	O
76	pH probe or signal failure.	Failure would result in incorrect pH control and deterioration of effluent quality.	Repair or replace failed equipment immediately. Calibrate and clean every shift or as needed. Maintain spares at CTP.	B, O
CIA Sludge Pond				
77	High AMD flow and strength requires excessive wasting of sludge volume, causing existing sludge pond to approach its capacity.	If alternate (new) sludge pond is not yet available, this would restrict or prevent sludge wasting/disposal, and could ultimately require CTP shutdown.	Divert AMD to in-mine storage until high flows recede. Design and construct a new sludge disposal cell sufficiently soon to alleviate the potential for this failure mode.	B

[a] Category codes (see Table 2 for further description): A = high priority; B = medium priority; C = low priority; O = O&M item

Yellow highlighting indicates items that are incomplete, pending additional information.